AEROSPACE REPORT NO.
ATR-79(7642)-1

Effects of the Solar Wind on Magnetospheric Dynamics: Energetic Electrons at the Synchronous Orbit

Prepared by G. A. PAULIKAS and J. B. BLAKE
Space Sciences Laboratory

27 November 1978

Prepared for NASA GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

Contract No. NAS5-23788

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ACKNOWLEDGEMENTS

We wish to thank Henry Hilton, Marie Wray, Gloria Holt and Adrienne Moon for their contributions to reduction and analysis of data spanning several spacecraft and more than a decade of time. This work was supported by NASA Contract NAS5-23788.

ABSTRACT

Data on energetic electron fluxes at the synchronous orbit, covering the 1967-1978 time interval, obtained by experiments flown on the ATS-1, ATS-5 and ATS-6 spacecraft, have been analyzed. Long term (year) and short term (days) electron flux averages are found to correlate positively with corresponding averages of the solar wind velocity.

CONTENTS

FIGURES

FIGURES (Continued)

I. Introduction

One of the fundamental questions in magnetospheric physics concerns the connection between the interior dynamics of the magnetosphere and the input into the magnetosphere of energy, momentum and mass by the solar wind. Viewing the solar wind-magnetosphere interaction in a macroscopic way, various workers have sought to establish the connections between the parameters which characterize the solar wind and the resulting geophysical effects. Knowledge of the variation of the strength of this interaction as a function of solar wind parameters is important in the testing of theories of magnetospheric dynamics. More practically, an unambiguous association of geomagnetic effects with the parameters of the solar wind could lead to long term and short term predictions of geomagnetic activity and the levels of space radiation.

The approach frequently used in studying the macroscopic interaction of the solar wind with the magnetosphere consists of correlating the parameters of the solar wind with direct or indirect measures of the energy content of the magnetosphere or the rate of dissipation of magnetospheric energy. In such an approach, which we shall follow, the details of the microscopic processes are ignored and global quantities describing the state of the magnetosphere are related to those parameters of the solar wind thought to be governing the efficiency of the coupling process. Russell et al. (1974) considered the conditions existing in interplanetary space associated with the development of the main phase of magnetic storms. Kivelson et al. (1973) studied the influence of the direction of the interplanetary field on the location of the polar cusp. Crooker et al. (1977) correlated long-term averages of the solar wind speed with geomagnetic activity. Arnoldy (1971) and Caan et al. (1977) studied the signature in the interplanetary medium associated with the occurrence of substorms. Akasofu (1975) and Burch (1973) examined the effect of the interplanetary magnetic field direction on auroral zone dynamics, and Burton et al. (1975) developed a relationship between the rate of injection of energy into the magnetospheric ring current and the interplanetary $E_y = -(V \times B)_y$ field. The citations above are meant to be a representative, not exhaustive, review of recent work in the field. These papers and the review by Russell (1974) should be consulted for additional details and references.

The picture which emerges from the work cited earlier is that the interplanetary magnetic field direction as well as the solar wind velocity determine the efficiency of coupling between the solar wind and magnetosphere. It has been known, for some time now, that during times when the magnetosphere "sees" a net southward interplanetary magnetic field, the interaction between the solar wind and the magnetosphere (presumed to be proceeding via magnetic merging) is enhanced, leading to enhanced geomagnetic activity and various effects resulting from such activity. It has been shown that, while the presence of a net southward field correlates very well with geomagnetic activity when this correlation is examined on a time scale of an hour, such a correlation may not hold true for longer averages of the parameters to be correlated. Crooker et al. (1977) have demonstrated that on time scales of the order of a year, correlation between geomagnetic activity, as expressed by the Ap index, and solar wind parameters scales as approximately as $B_z V^2$, where V is the average solar wind velocity and B_z is the southward component of the interplanetary magnetic field in GSM coordinates. The work of Crooker et al. has been criticized by Dessler and Hill (1977), who point out that earlier work by Garrett et al. (1974) had shown that the positive derivative of the solar wind speed is the factor controlling geomagnetic activity. It is thus of interest to continue work along these lines, looking both at time scales intermediate to those discussed above as well as at correlations between the parameters of the solar wind and various other magnetospheric observables.

We have recently presented a preliminary report (Paulikas and Blake, 1976) in which we showed that the sector structure of the interplanetary magnetic field exerted a strong influence on the intensity of energetic electrons contained in the outer magnetosphere. Specifically, we found that in the fall, more energetic electrons are found when the earth is in a positive sector of the interplanetary field (with a consequent net southward B_z) than when a negative sector envelops the magnetosphere. The situation is reversed in the spring, and negative interplanetary magnetic field sectors appear to be able to generate larger fluxes of energetic magnetospheric electrons. These findings, based on a relatively limited set of data obtained in late 1974-early 1975, were interpreted in the context of the work of Burton et al. (1975) and Russell and McPherron (1973) who viewed energetics of the magnetosphere as being influenced primarily by the north-south component of the interplanetary field.

These conclusions were based on limited data and no attempt was made to correlate the behavior of energetic electrons in the magnetosphere with the various parameters which describe the interplanetary medium. We have since extended our data base on energetic electrons substantially in time and have acquired data on the properties of the interplanetary medium during the period of interest. This paper presents the results of a study correlating the observations of energetic electrons at the synchronous orbit in the 1974-1977 interval with the state of the interplanetary medium. In addition, we also present here an overview of the behavior of energetic trapped radiation at the synchronous altitude since 1967.

II. Description of the Data

Energetic electrons at the synchronous orbit were measured by the Aerospace Corporation experiment on ATS-6. Additional data, used to compile the 1967-1977 history of energetic electron radiation at the synchronous orbit, were obtained by our earlier experiment on ATS-1 and the UCSD instrument on ATS-5. The latter data were graciously provided to us by C. E. McIlwain. The periods of data coverage relative to the recent history of solar activity, as described by the Zurich sunspot number, are shown in Figure 1. The details of the instrumentation have been described in detail elsewhere (Paulikas et al., 1968, 1975). Briefly, the experiments measured the fluxes of energetic (mainly relativistic) electrons. We are using the flux of relativistic electrons as an indication of the efficiency of the solar wind – magnetosphere engine: these particles

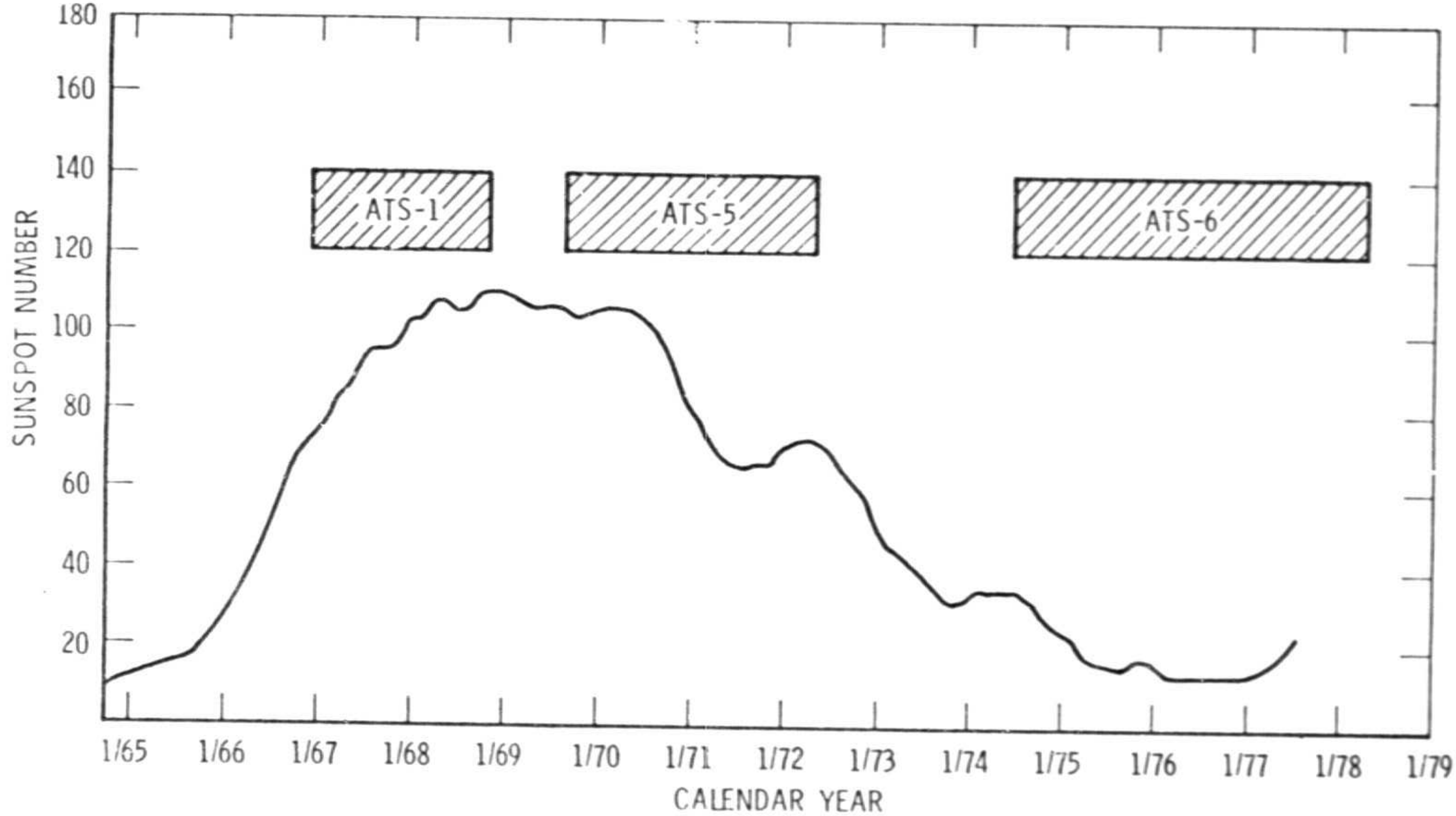

Figure 1. Relationship between the intervals of data acquisition on energetic electrons at synchronous altitude by experiments on board ATS spacecraft and the 11-year solar activity cycle as defined by the Zurich sunspot number.

are a measure of the capability of magnetospheric processes to generate relativistic particles from thermal plasma.

It is useful to recall that the synchronous orbit is well beyond the maximum of energetic trapped radiation (Fig. 2) and that the particles of concern in this paper are the extreme high energy tail of the spectrum (Fig. 3). The particles of concern can be thought to be end products of magnetospheric dynamics, but not as participants, owing to their very low energy density. Because we are dealing with omnidirectional fluxes in our data, our conclusions apply to a sizeable volume of the outer magnetosphere: as a result of drift shell splitting, the electrons detected at one local time spread over a band of L-shells at other local times (Fig. 4), and a local measurement acquires global properties.

Data on the sector structure of the interplanetary field were obtained from the reports of Svaalgard (1976). Information on the state of the interplanetary medium was obtained from the NSSDC tape. The solar wind velocities for the recent past were obtained from Jack Gosling at Los Alamos. The best temporal resolution of data used for the present purposes was typically one hour for the solar wind data and one day for the data on the sector structure of the interplanetary magnetic field.

III. Approach

In this study we are interested in the long-term behavior of the energetic electrons. Accordingly, we have chosen as the basic unit of data for most of our analyses the daily average of the electron flux and the corresponding daily averages of the parameters of the solar wind. The daily average was chosen in order to average out local time effects which are very important for energetic electrons at the synchronous orbit (Paulikas et al., 1968). A day is also the natural timescale on which to view the longer term dynamics of energetic electrons in the outer zone. Growth and decay of the

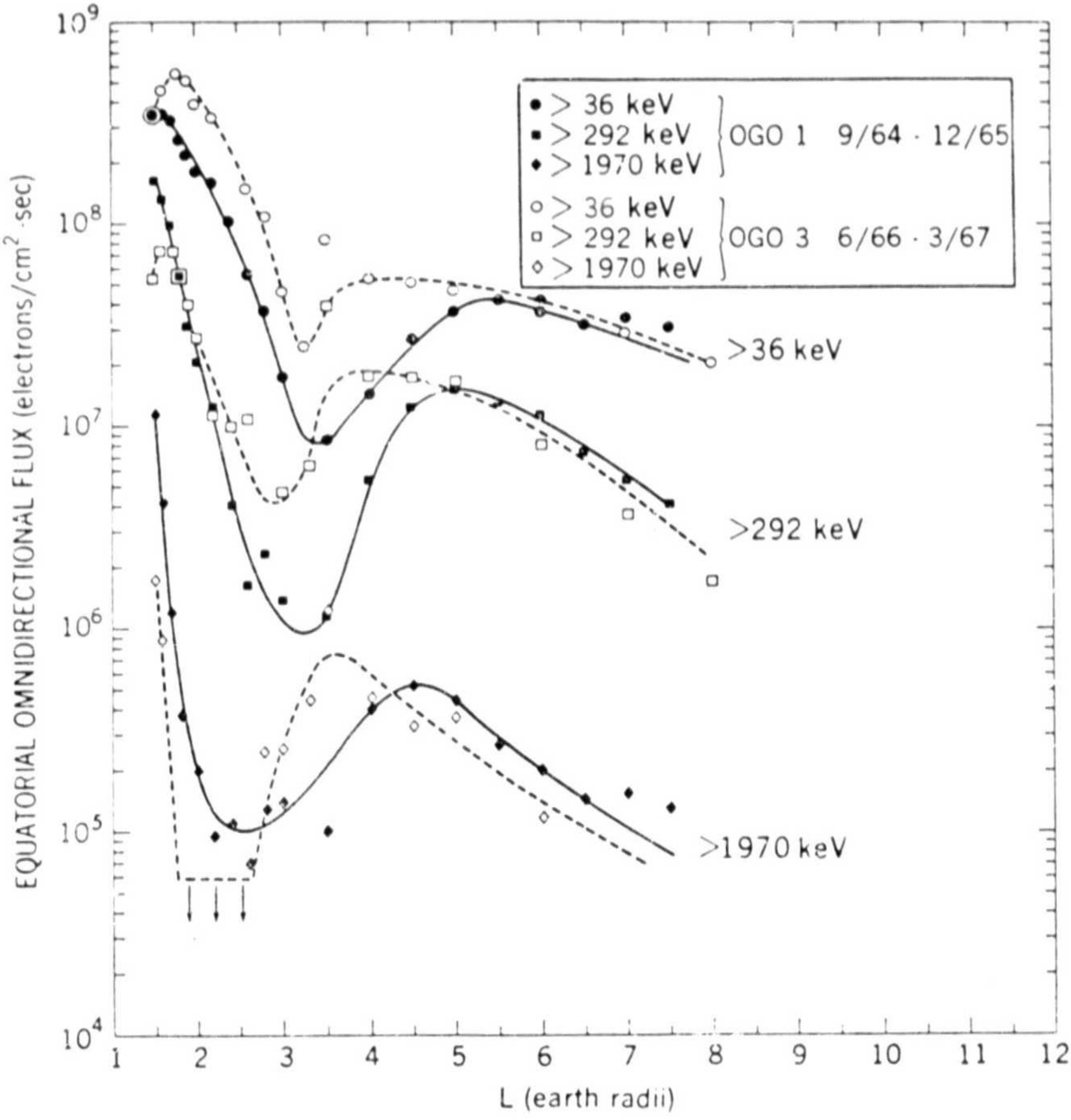

Figure 2. Equatorial radial profiles of energetic electrons obtained from OGO data (from Singley and Vette, 1972)

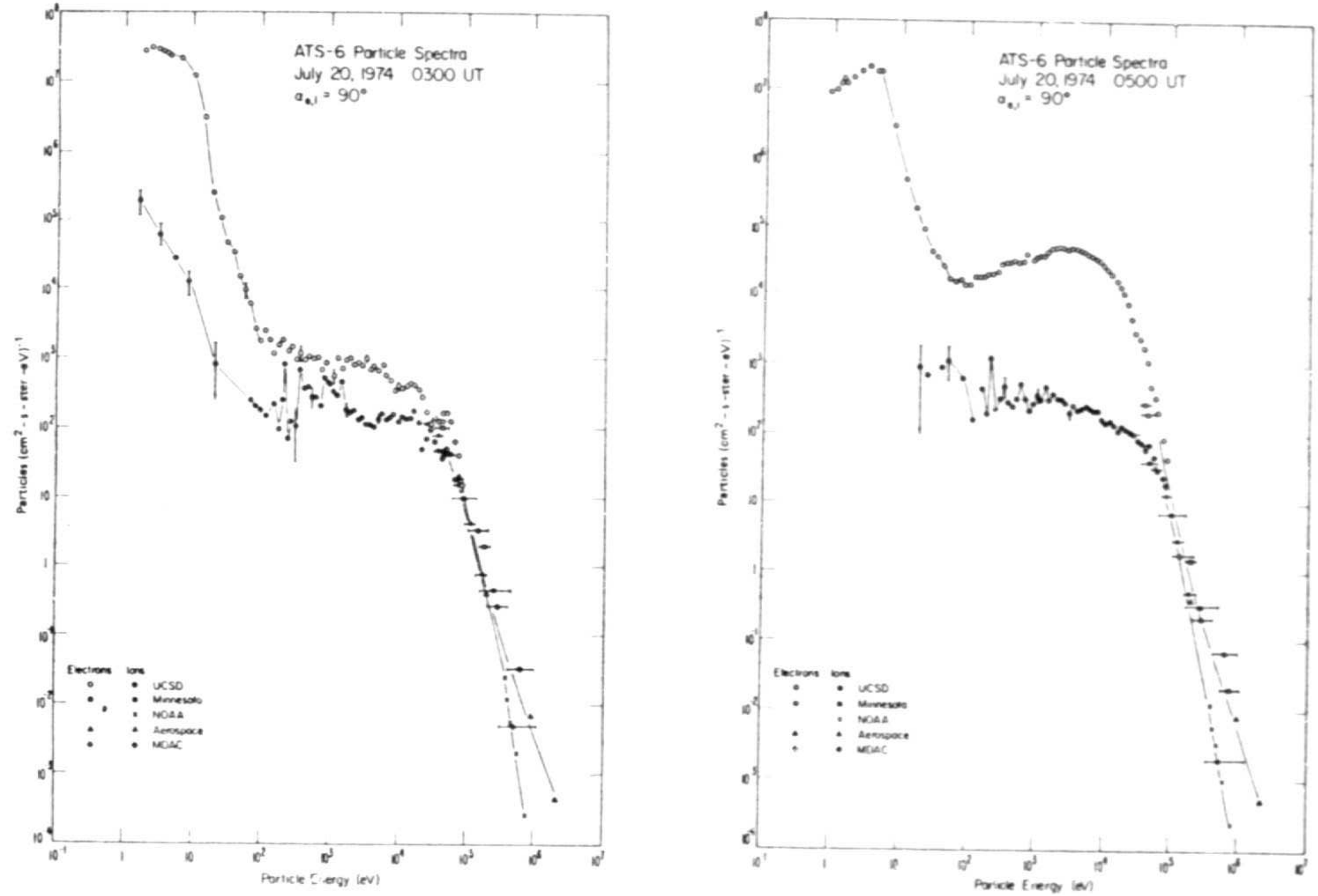

Figure 3. Electron and proton energy spectra observed by the ATS-6 experiments at two different times (Fritz et al., 1977). The present paper addresses the behavior of the extreme high energy tail of the electron population.

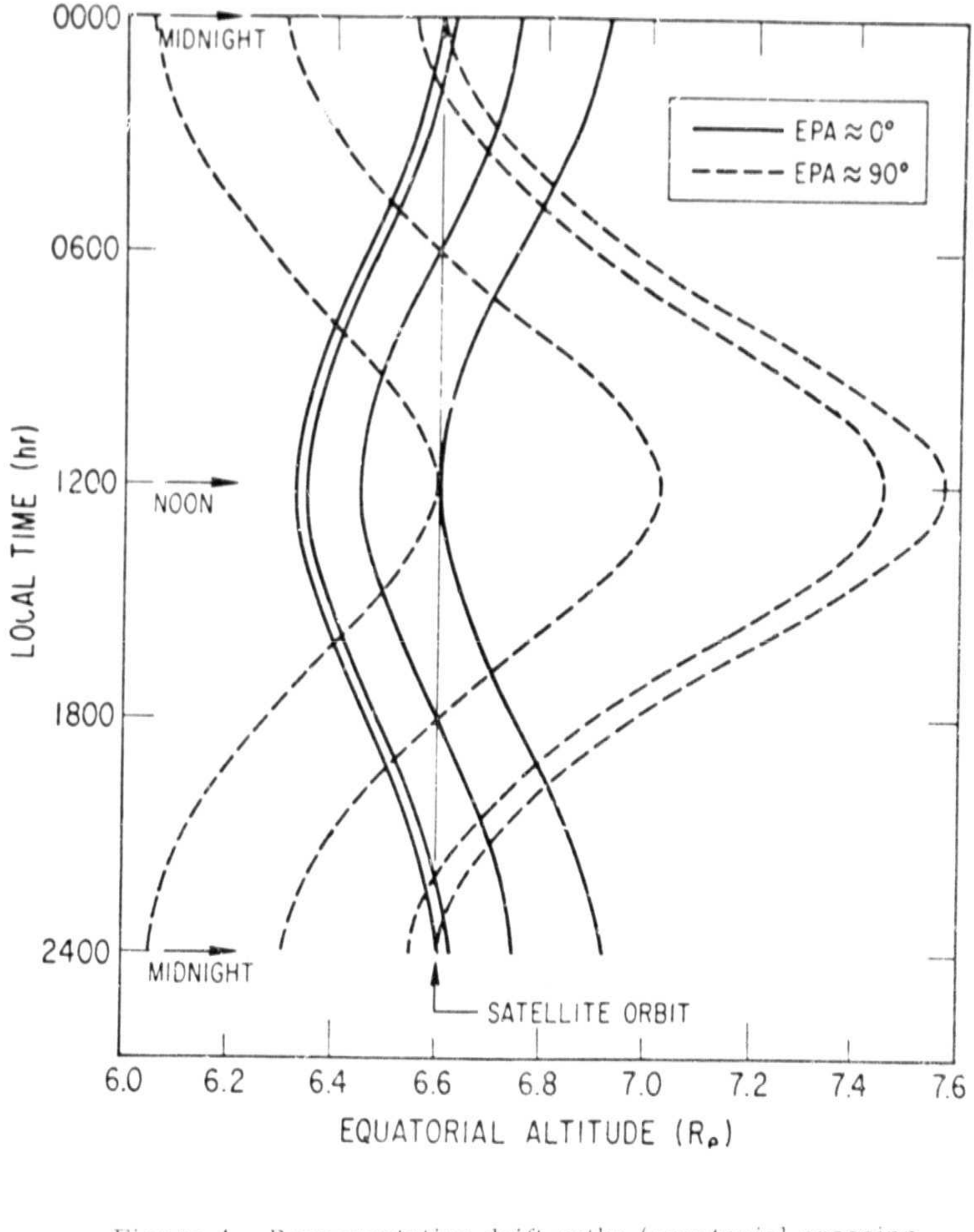

Figure 4. Representative drift paths (equatorial crossing altitudes) of electrons for particles mirroring near the equator (EPA ≈ 90°) and those mirroring at high latitudes (EPA ≈ 0°)

energetic electron populations seems to occur on the time scale of many hours or days at least in part because diffusive effects appear to delay arrival of energetic electrons at the synchronous orbit from the inner magnetosphere where the peak of the energetic electron flux is usually found. For the present purpose, we have not eliminated adiabatic perturbations of electron flux from our data, although such a correction is possible. Such limited examination as we have made of the magnitude of adiabatic effects on the electron fluxes relative to non-adiatatic effects suggests that non-adiabatic effects are at least an order of magnitude more important in the dynamics of relativistic electrons at synchronous altitude at most times and totally dominate the dynamics during periods of electron flux increase.

The integrated effect of our data analysis approach is to view the magnetosphere as a black box, with the solar wind parameters as the input and the fluxes of energetic electrons at the synchronous altitude as the output. We seek information on the transfer function which will tell us the dependence of the generation of energetic electrons by magnetospheric processes on the parameters of the solar wind. The transfer function we seek thus incorporates implicitly within such details as the source functions of plasma in the magnetosphere, substorm processes, as well as subsequent transport and acceleration processes which, taken together, generate the high energy tail of the spectra illustrated in Fig. 3.

In this paper we have chosen the ATS-6 data for detailed study of the solar wind-energetic electron correlation. The ATS-1 and ATS-5 data base are used to extend our data base so that with only simple normalizations we are able to reconstruct the behavior of the energetic electron population for a large fraction (1967-1978) of a complete solar cycle and thus infer additional details about the behavior of energetic electrons in the outer zone over this time span.

IV. Effect of Solar Wind Parameters on Energetic Electrons

A. Prototype Observations and Interpretations

Figures 5, 6 and 7 present data on energetic electrons and the solar wind velocity for each of three solar rotations. Figure 5 illustrates the case, common in 1974 and 1975, when the sun was emitting two streams of plasma with unusually high velocity (Bame et al., 1976, Gosling et al., 1976, 1977, Feldman et al., 1978) and the subsequent response of the energetic electron population in the outer magnetosphere to these solar wind streams. Figures 6 and 7 show an opposite extreme, commonly noted in 1976 and 1977: the solar wind streams here are much weaker, reaching maxima of barely 600 km/sec, in contrast to the 800 km/sec peaks evident in Fig. 5.

In either event the response of magnetospheric energetic electrons is evident. Starting about a day or two after the solar wind stream first reaches the earth, the fluxes build up in correlation with the increasing velocity of the solar wind. The delay between arrival of a high speed stream and buildup of energetic fluxes appears to depend on the energy of the electrons under observation, with the delay of the response of the electrons increasing with electron energy. Subsequent to the passage of the peak in the solar wind velocity, electron fluxes in general do not track the decay in the velocity of the stream.

Similar comparisons have been made between energetic electron fluxes and other parameters which describe the solar wind, for example, solar wind energy density, solar wind pressure, the components of the interplanetary field, and the components of $-V \times B$. From these comparisons it soon became clear that the approximately exponential relationship between electron flux and solar wind velocity ($J \alpha \exp V_{sw}$) evident from

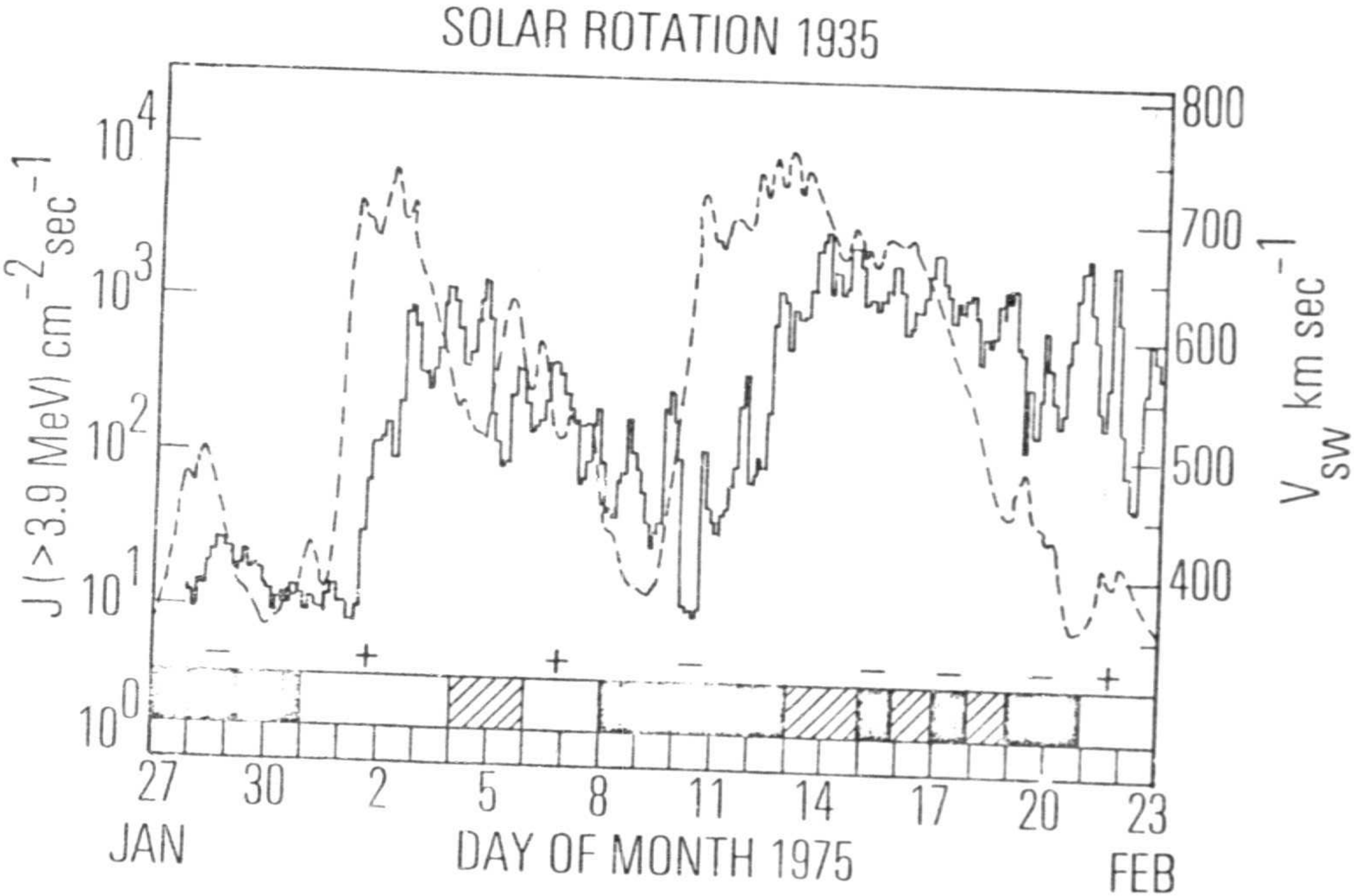

Figure 5. Flux of energetic electrons (solid curve with logarithmic scale at left) as a function of time for solar rotation 1935. Three-hour averages of electron flux are plotted. Solar wind velocity (dashed curve with linear scale at right) is superimposed on these data. The pattern at the bottom of the figure is represents the IMF sector structure.

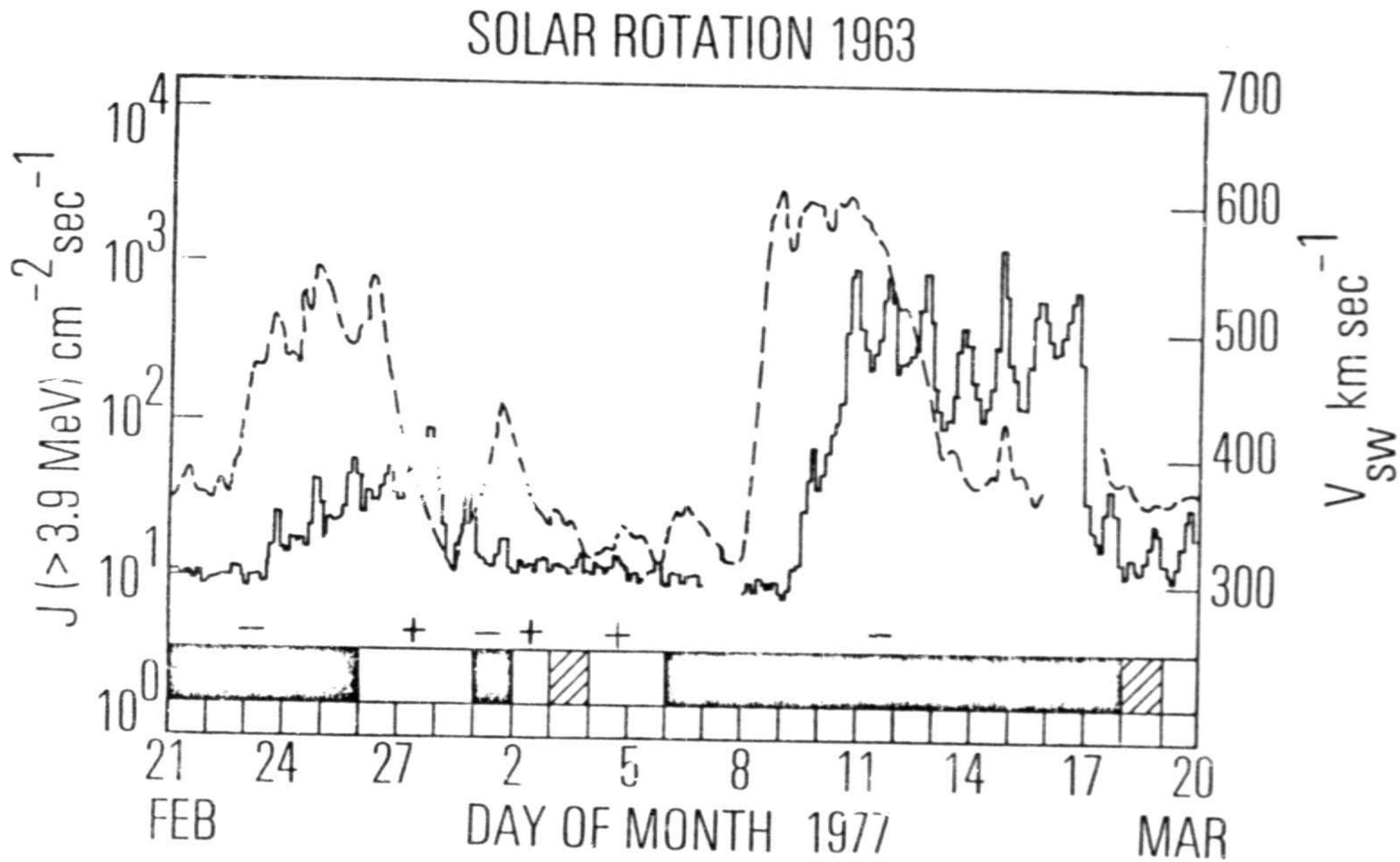

Figure 6. Flux of energetic electrons (solid curve with logarithmic scale at left) as a function of time for solar rotation 1963. Three-hour averages of electron flux are plotted. Solar wind velocity (dashed curve with linear scale at right) is superimposed on these data. The pattern at the bottom of the figure represents the IMF sector structure.

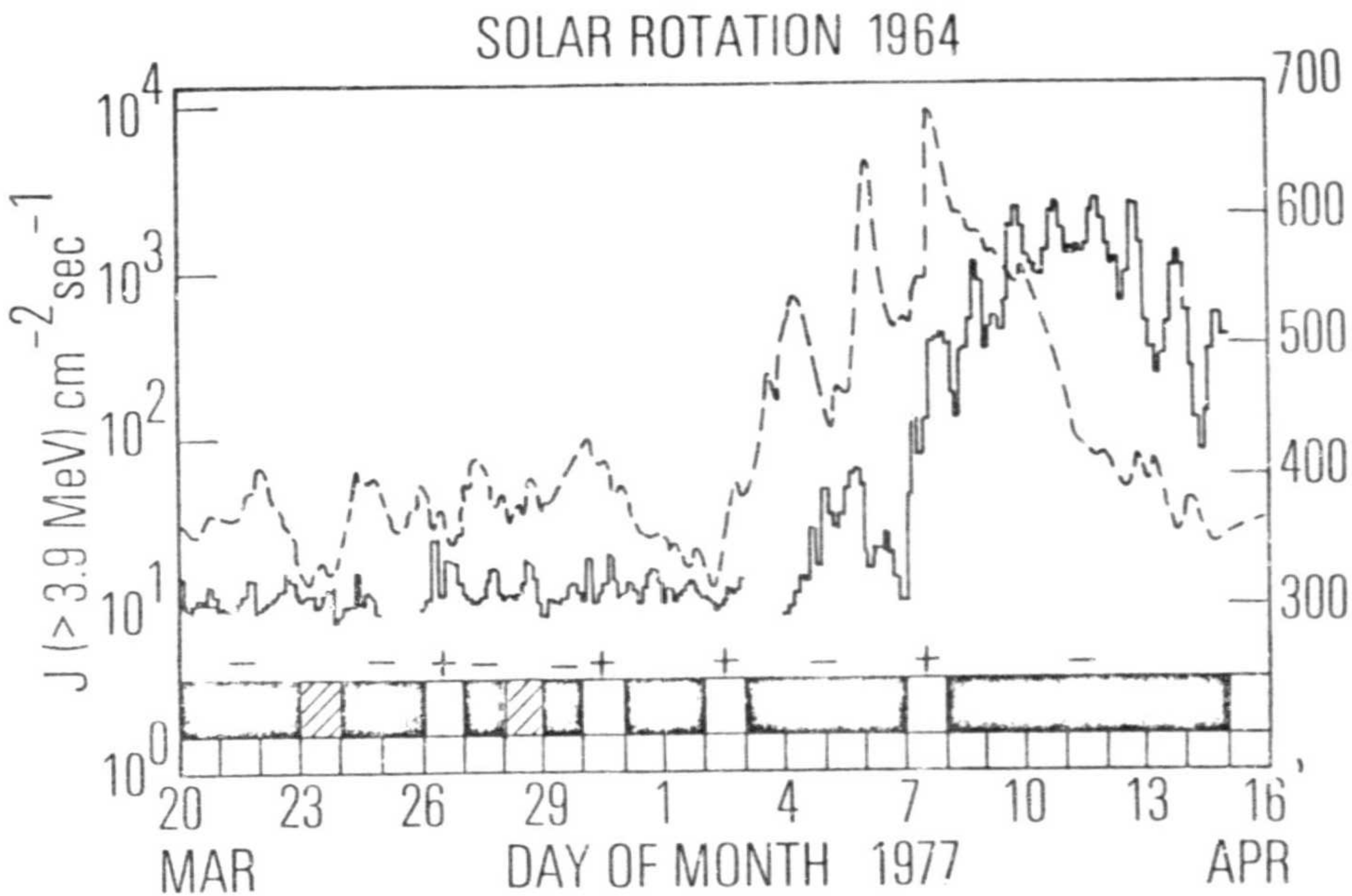

Figure 7. Flux of energetic electrons (solid curve with logarithmic scale at left) as a function of time for solar rotation 1964. Three-hour averages of electron flux are plotted. Solar wind velocity (dashed curve with linear scale at right) is superimposed on these data. The pattern at the bottom of the figure represents the IMF sector structure.

inspection of Figures 5, 6 and 7 was the most pronounced signature of solar wind variability in the dynamics of energetic electrons.

Examination of more than three years of ATS-6 data serves only to confirm the picture described above. The flux of energetic electrons at the synchronous altitude is strongly correlated with the presence of high speed streams in the solar wind. A well-ordered stream pattern gives rise to a regular sequence of electron flux growth and decay, a disordered flow pattern (i.e. a highly variable solar wind velocity) gives rise to a more chaotic behavior in the energetic electron population. The correlation between solar wind velocity and energetic population is most striking at the time of solar velocity increase. Once past the velocity peak, the behavior of the energetic electrons appears to be a combination of continued lower level injection (or diffusion) of energetic electrons into the region of space accessible to our observations, ultimately followed by rapid decay of the electron flux.

B. Quantitative Comparisons

In order to arrive at a quantitative measure of the effect of solar wind velocity on the population of energetic electrons, we have made detailed correlations of the rise of electron fluxes with the solar wind velocities. As briefly noted above, we observe that a finite time delay appears to be required for energetic electrons to respond to changes in solar wind velocity. These differences in time required by the various electron energy channels to respond to changes in the solar wind can be taken to be a measure of the time the magnetosphere requires to generate energetic electrons and to transport these particles to the synchronous orbit. Thus, very approximately we find that about a day is needed to generate 140-600 keV electrons, while two days are required to generate > 3.9 MeV electrons. Such time delays have been incorporated in our correlation analysis and the results are presented in Figures 8 through 11. Similar plots have been made with other choices of time delays. We find that the delays used in Figures 8-11 minimize the scatter of the data points in that for both shorter or longer delays the correlation of electron fluxes with solar wind velocity is less clear cut.

We have also looked for a correlation of the energetic electrons with $E_y = -(V \times B)_y$, following the lead of other workers. One such correlation plot is shown in Figure 12. As can be seen, the dependence of the flux of > 3.9 Mev electrons on E_y is not nearly as strong as the dependence of the electron flux on the solar wind velocity. To be sure, the sign of $-(V \times B)_y$ viewed in geocentric solar-magnetospheric coordinates exerts a modulating influence even on the time scale of one day and appears to modulate the effectiveness of the solar wind in determining the maximum flux level that energetic electrons may reach. Examination of Figure 9-12 reveals that the maximum fluxes occur preferrentially when $E_y > 0$, (i.e. B_z is pointing south), in agreement with the accepted view of interplanetary magnetic field - magnetosphere interaction. It could be argued that daily averages of E_y suppress short period excursions of the interplanetary field and thus do not correctly represent the effects of short duration southward B_z. Examination of our IMF data base down to a temporal resolution of one hour shows that such a bias is not present, although examination of IMF data at higher time resolution has not been carried out. .

The picture which emerges is thus one where the velocity of the solar wind is the most important parameter in organizing the flux levels of energetic electrons in the outer magnetosphere, with the sign of the $E_y = -(V \times B)_y$ component modulating the efficiency of the solar wind velocity as a "generator" of energetic electrons.

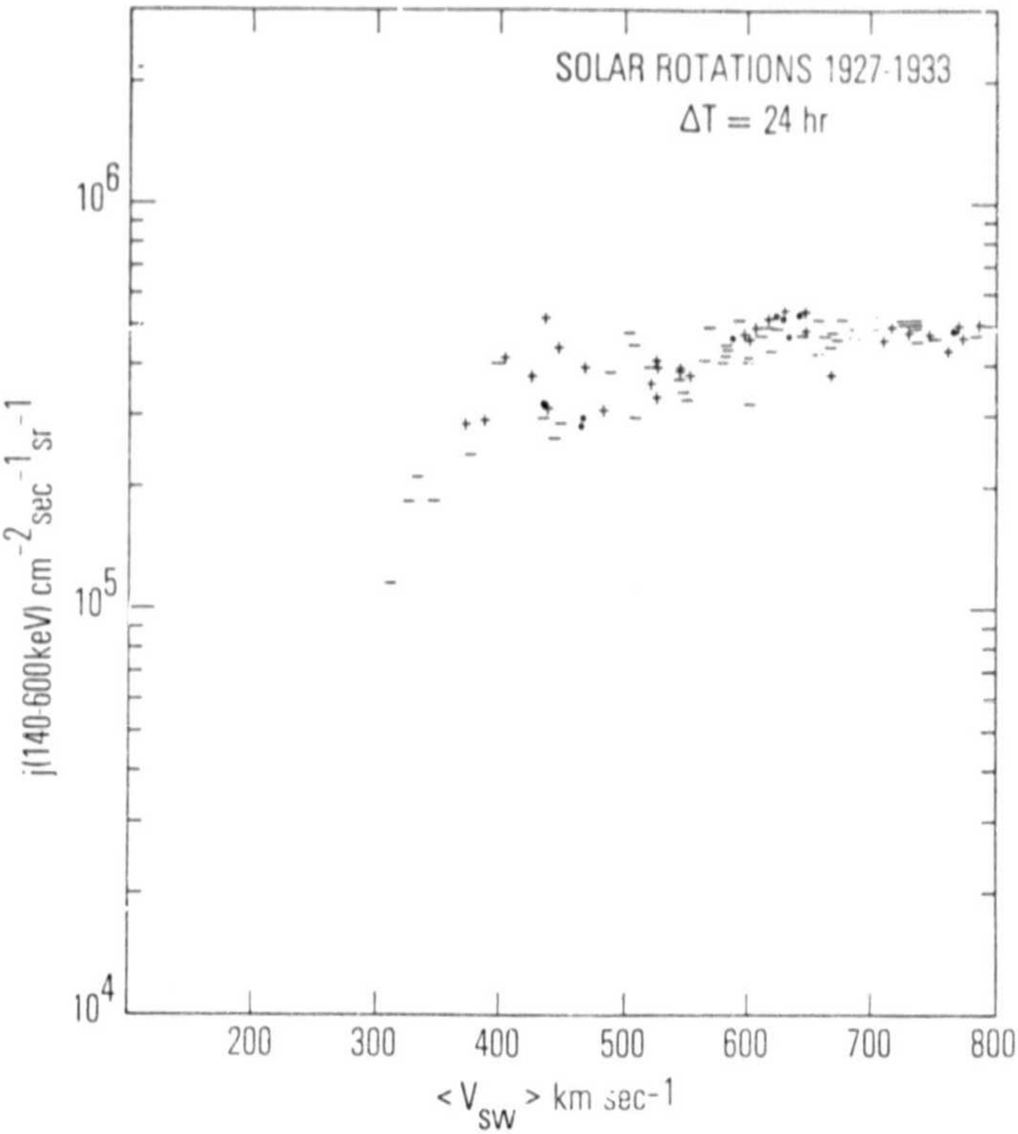

Figure 8. Correlation of daily averages of 140-600 kev electron fluxes with daily averages of the solar wind velocity. The delay time between solar wind and energetic particle measurements is 12 hours. All data available for solar rotations 1927-1933 (July-December 1974) are included in this plot. The plus and minus signs indicate the sign of $E_y = -(V \times B)_y$ in geocentric solar magnetospheric coordinates; data points for which the E_y sign cannot be determined are simple points.

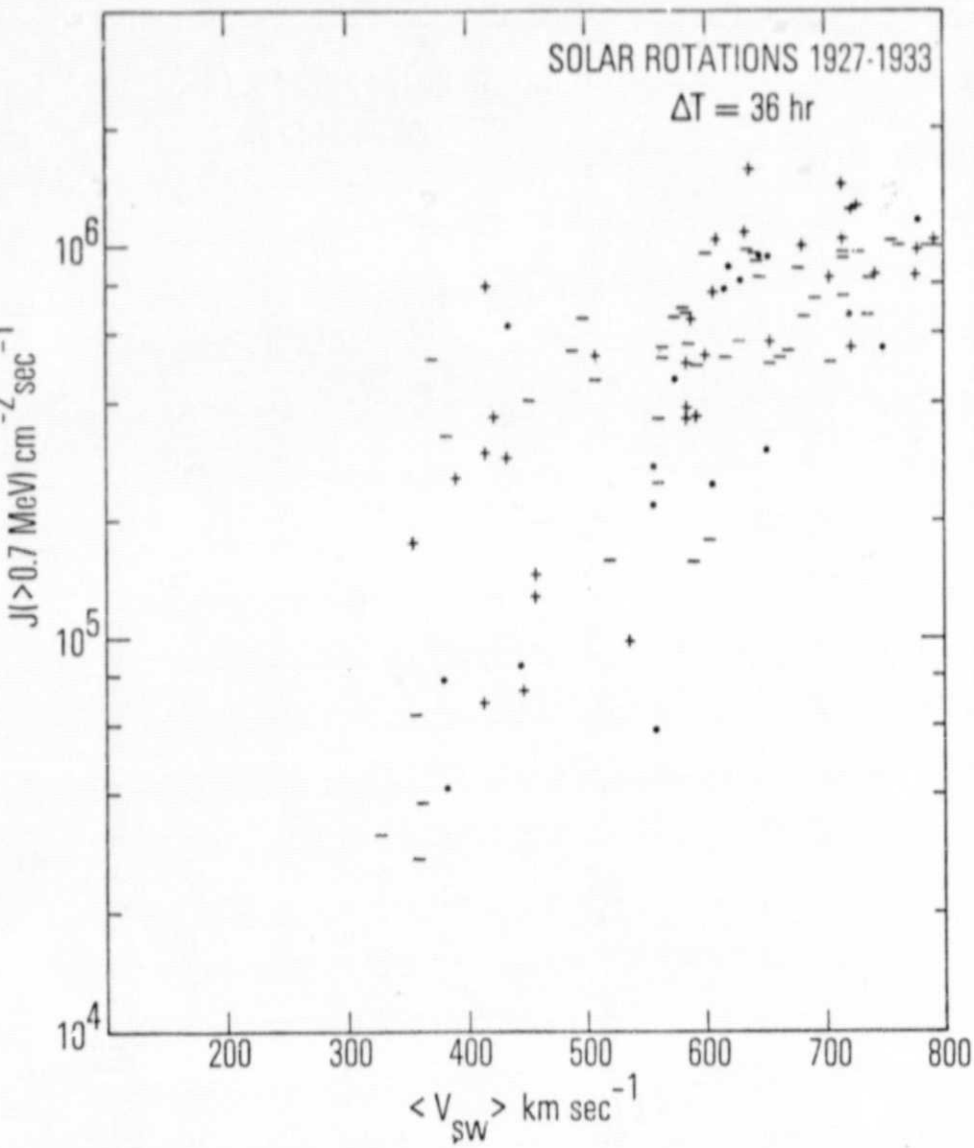

Figure 9. Correlation of daily averages of greater than 0.7 MeV electron fluxes with daily averages of the solar wind velocity. The delay time between solar wind and energetic particle measurements is 24 hours. All data available for solar rotations 1927-1933 (July-December 1974) are included in this plot. The plus and minus signs indicate the sign of $E_y = -(V \times B)_y$ in geocentric solar-magnetospheric coordinates; data points for which the E_y sign cannot be determined are simple points.

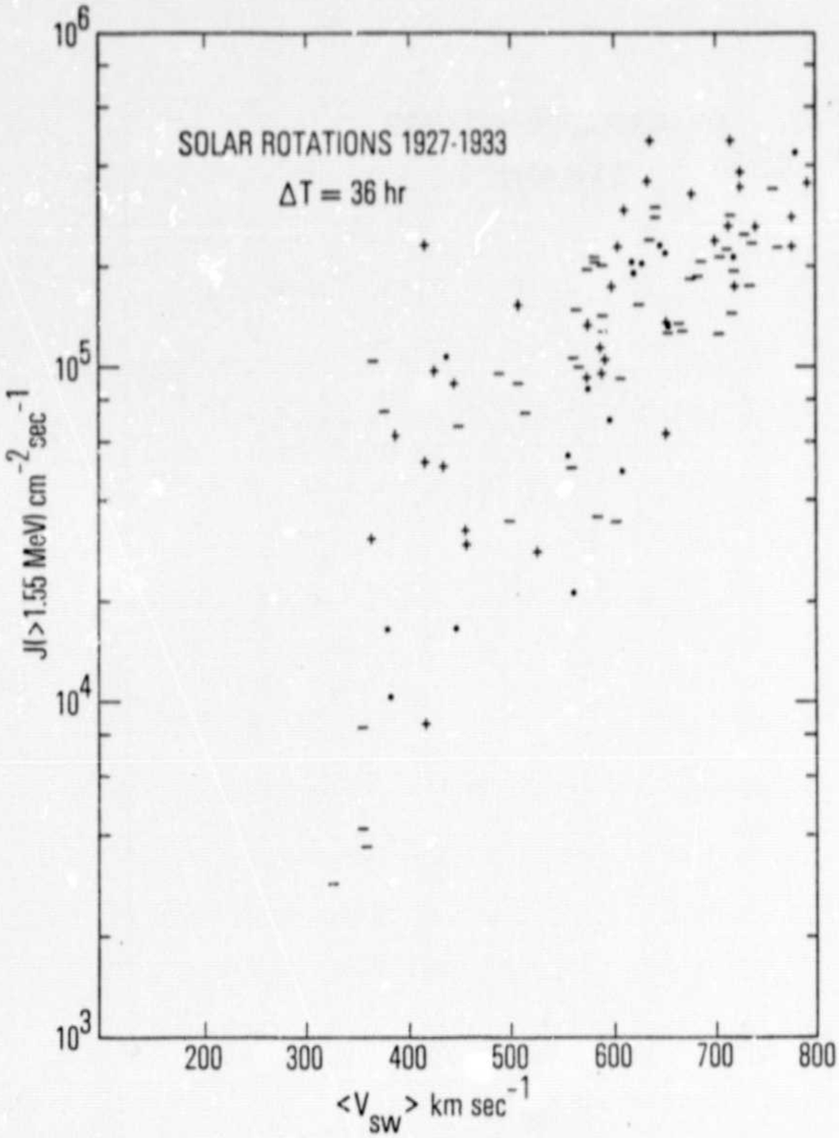

Figure 10. Correlation of daily averages of greater than 1.55 MeV electron fluxes with daily averages of the solar wind velocity. The delay time between solar wind and energetic particle measurements is 36 hours. All data available for solar rotations 1927-1933 (July-December 1974) are included in this plot. The plus and minus signs indicate the sign of $E_y = -(V \times B)_y$ in geocentric solar-magnetospheric coordinates; data points for which the E_y sign cannot be determined are simple points.

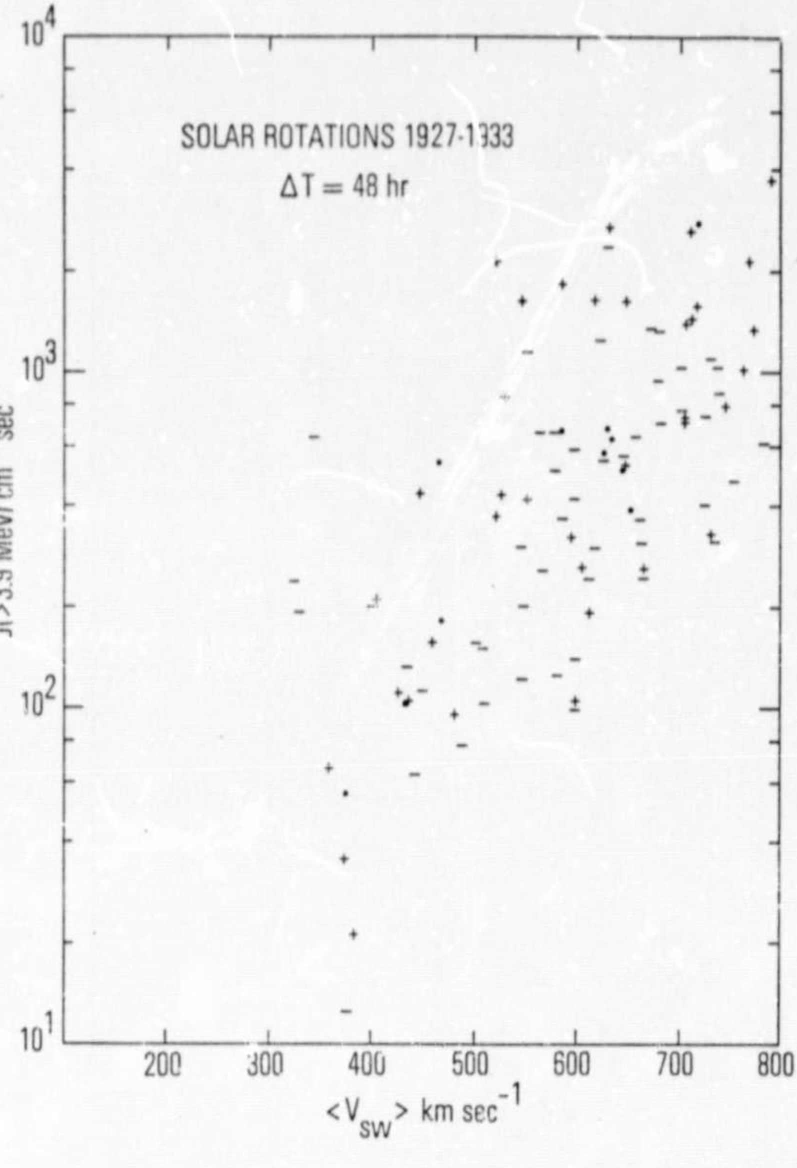

Figure 11. Correlation of daily averages of greater than 3.9 MeV electron fluxes with daily averages of the solar wind velocity. The delay time between solar wind and energetic particle measurements is 48 hours. All data available for solar rotations 1927-1933 (July-December 1974) are included in this plot. The plus and minus signs indicate the sign of $E_y = -(V \times B)_y$ in geocentric solar-magnetospheric coordinates; data points for which the E_y sign cannot be determined are simple points.

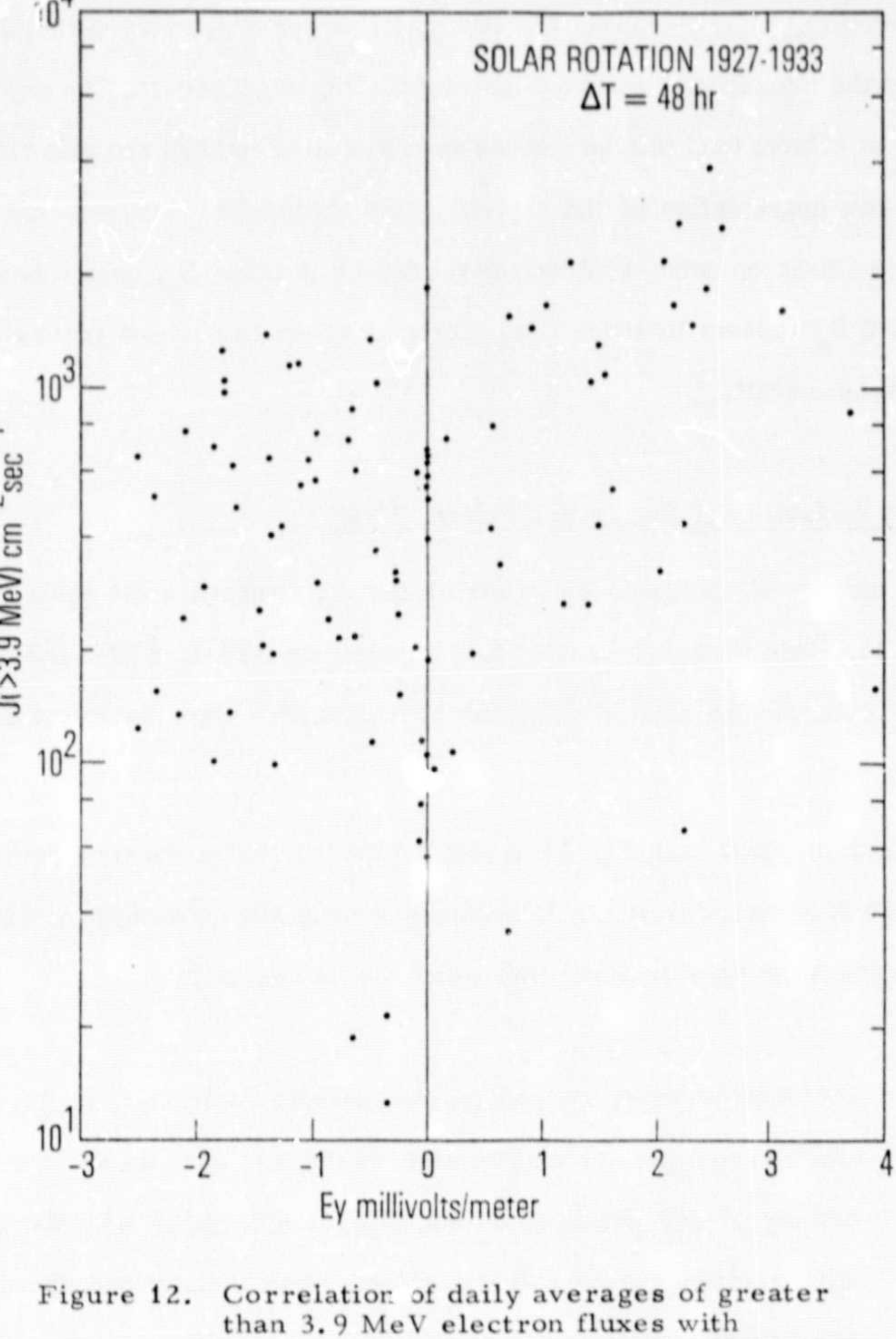

Figure 12. Correlation of daily averages of greater than 3.9 MeV electron fluxes with $E_y = -(V \times B)_y$ in GSM coordinates. Data on this plot are identical to that presented in Figure 11.

Our earlier findings (Paulikas and Blake, 1976) can now be re-examined in this light. Figures 13 and 14 are reproduced from our earlier paper, but with the addition of the solar wind velocity. It is clear that the electron flux peaks coincide with the peaks in the velocity of the high speed solar wind imbedded within each sector. The arguments relating to seasonal effects (and thus an implied semi-annual variation) are still relevant, modified by our new appreciation of the explicit - and exponential - dependence of the energetic electron fluxes on solar wind velocity. Strong positive E_y, corresponding to southward directed B_z appears to add a final factor of about two in energetic electron flux at the synchronous orbit.

V. Long-Term Variability of Energetic Electron Fluxes

The time history of energetic electrons at the synchronous orbit since 1967 is presented in Fig. 15. Here we are presenting data obtained by ATS-1, ATS-5 and ATS-6, with the ATS-5 data having been normalized to the ATS-6 data so as to form a homogeneous data set.

The overall impression from Fig. 15 is that during the 1967-1978 time period, the energetic radiation is remarkably stable if sufficiently long time averages of data are examined. There are three types of variability which deserve attention:

1) The most marked variability, particularly noticeable at the higher electron energies and exaggerated by the fact that we are presenting running 27-day averages of the data, is associated with the 27-day solar rotation period and the effect, already described above, that discrete high-speed solar wind streams are efficient generators of energetic electrons.

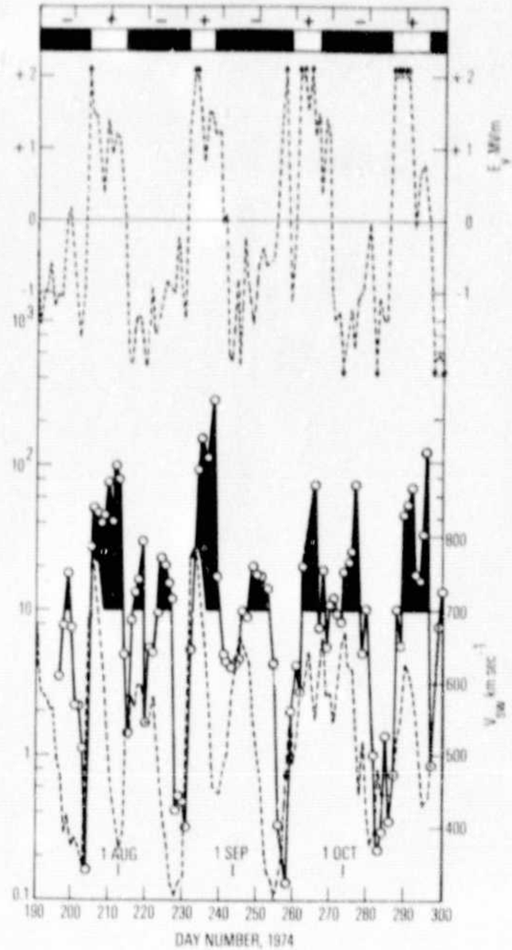

Figure 13. Daily averages of energetic electron countrates observed in the late summer and fall of 1974 by ATS-6 are plotted as a function of Day Number, 1974. Also plotted, at the top of the figure, are the polarities of the interplanetary magnetic field as inferred by Svalgaard (1976), and the strength of the dawn-dusk electric field $E_y = -(V \times B)_y$. Local time for all particle data is local noon; the sector boundary transitions are assumed to occur at 0000 UT for the days indicated. Solar wind velocity is shown at the bottom of the figure (dashed curve, bottom) referred to the right-hand scale. For emphasis we have shaded those portions of the curves where E > 3.9 MeV countrates exceed 10/sec.

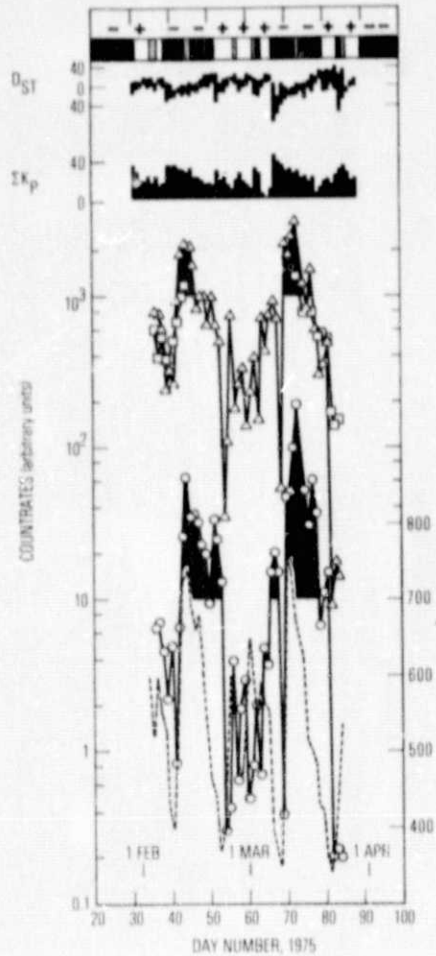

Figure 14. Daily averages of energetic electron countrates observed in the spring of 1975 by ATS-6 (triangles, $E_e > 1.55$ MeV, circles $E_e > 3.9$ MeV) and ATS-1 (squares $E_e > 1.9$ MeV). Also plotted, at the top of the figure, are the polarities of the interplanetary field as inferred by Svalgaard (1976) and the velocity of the solar wind, (dashed curve, bottom), referred to the right hand scale. The daily sum of Kp and the range of D_{st} for each day is also shown at the top. The IMF sector structure during this period exhibited some days of mixed polarity, these days are indicated by cross-hatching. Countrates greater than 10^3/sec (upper curve) and greater than 10/sec (lower curve) are shaded for emphasis.

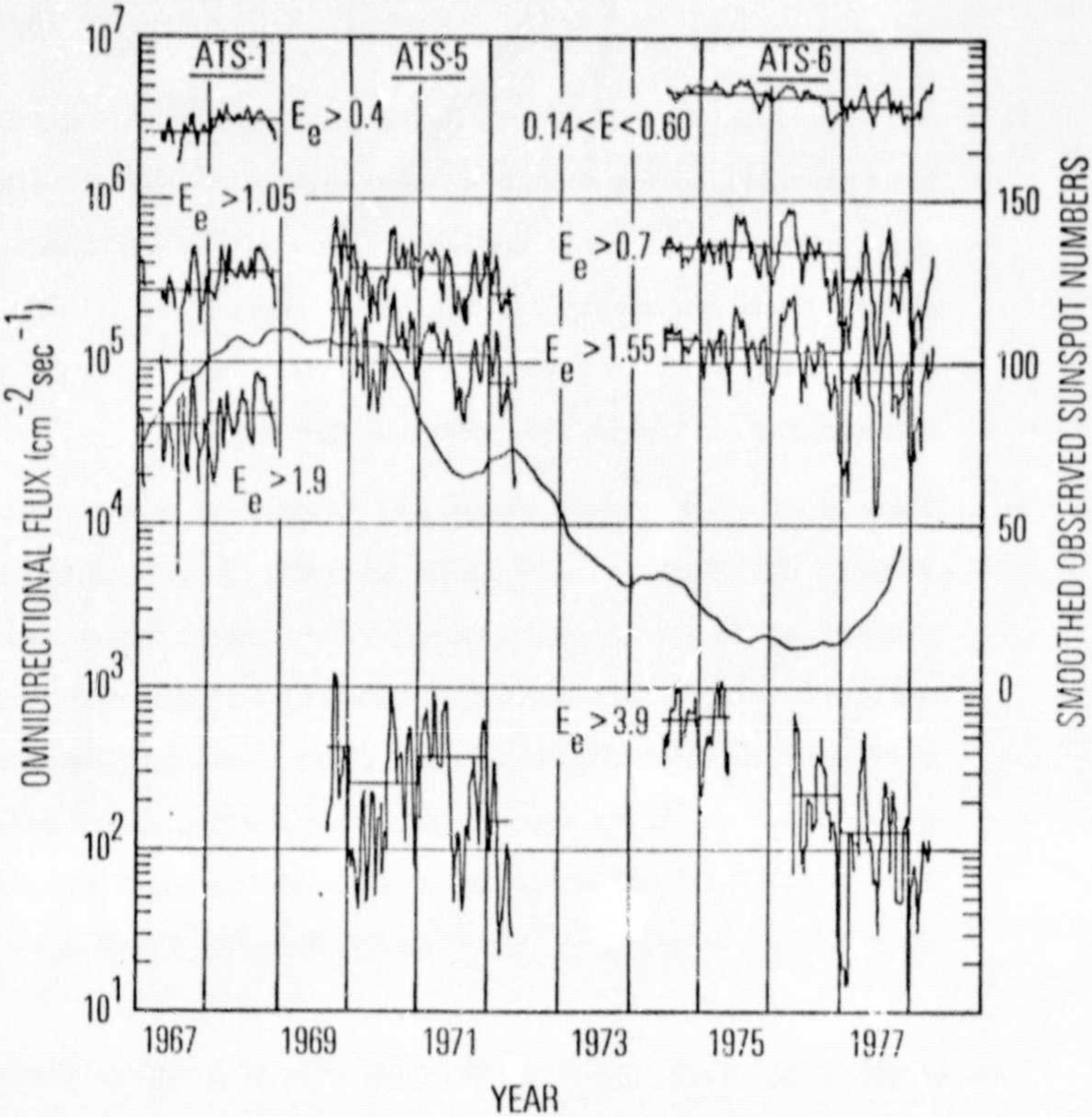

Figure 15. ATS-1, and ATS-5, ATS-6 energetic electron fluxes (running 27 day averages) as a function of time. ATS-5 data was normalized to ATS-6 data in mid 1974. The energy thresholds for the ATS-1, ATS-5 and ATS-6 channels are shown on the figure. The flux averages for each year are also indicated (solid horizontal lines). Superimposed on this graph is the Zurich monthly sunspot number, referred to the linear scale on the right. Gap in the ATS-6 $E_e > 3.9$ MeV data in 1975 and 1976 is caused by our rejection of suspect data.

Figures 16-18 present a correlation of 27-day averages of electron fluxes with corresponding averages of the solar wind velocity.

2) The general decrease in electron fluxes which began in 1976 appears to be associated with a decline in the average velocity of the solar wind. When we calculate semi-annual averages of the observed electron fluxes and compare these against averages of the solar wind (Figs. 19-21), we find, on this time scale a clear positive correlation between solar wind velocity and energetic electron fluxes.

3) There is some, admittedly qualitative, evidence of a semi-annual effect. This effect is particularly noticeable in 1977 when the observations are not confused by spacecraft movement (which occurred in 1975 and 1976) or systematic changes in the solar wind velocity as occurred in 1976. A semi-annual variability in energetic electrons should be a natural consequence of the semi-annual variation in the strength of the interaction between the interplanetary magnetic field and the magnetosphere as described by Russell and McPherron.

Thus we see, that, when viewed on the time scale of a day or a solar rotation (27-days) or even on the time scale of half a year, we find that the correlation of energetic electron fluxes with solar wind velocity persists (Figs. 16 through 21). Similar results have been obtained for energetic protons in the outer magnetosphere by Baker et al. (1978). There is some evidence that the "initial state" of the magnetosphere also exerts a significant influence on the evolution of the population of energetic electrons under the impact of changing interplanetary conditions. As mentioned earlier $-V \times B$ effects can be seen in our data, but only as a modulating influence.

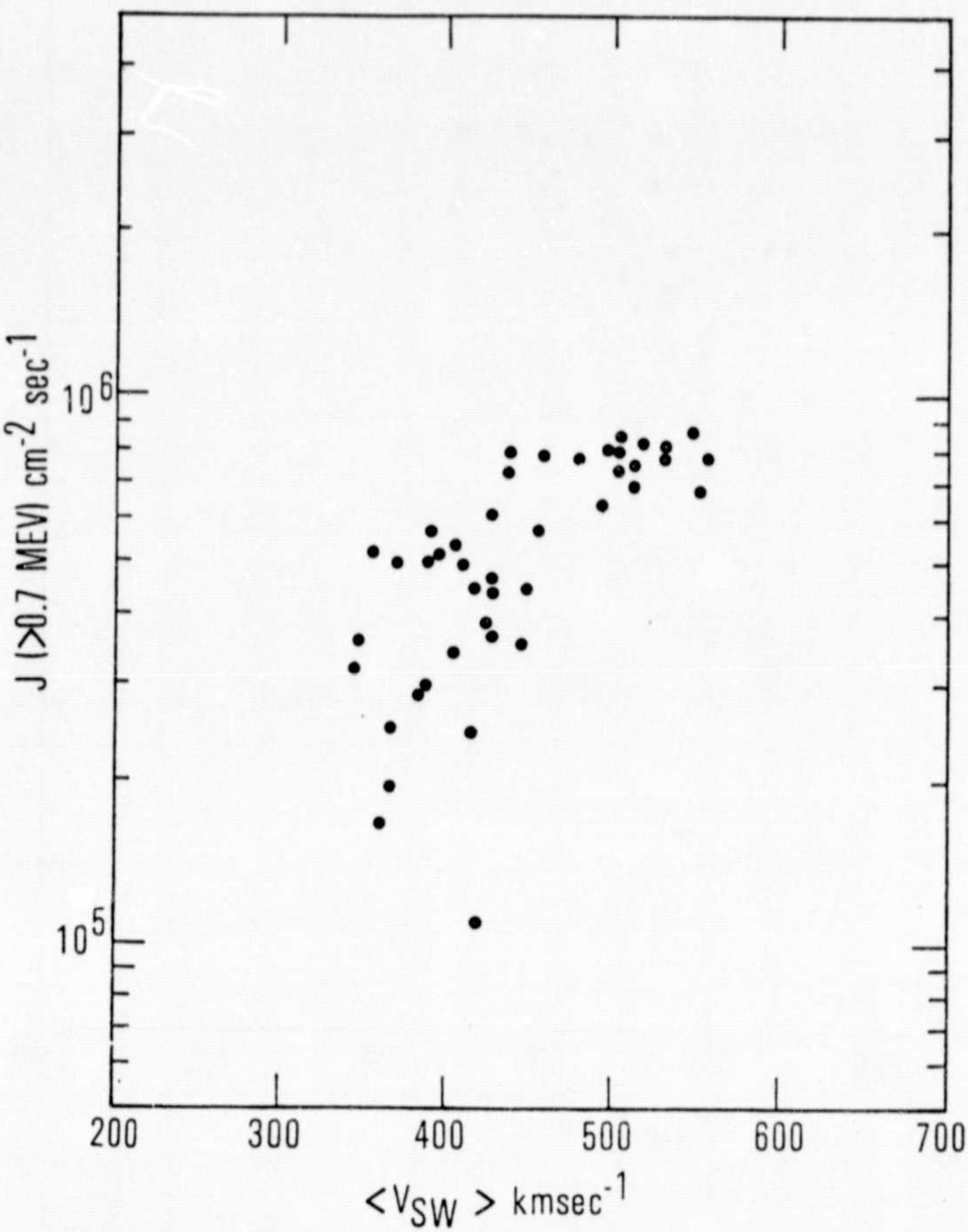

Figure 16. 27-day average of energetic electons ($E > 0.7$ MeV) as a function of corresponding averages of the solar wind velocity. All ATS-6 data for solar rotations 1927-1969 (June 1974 - August 1977) are included in this figure.

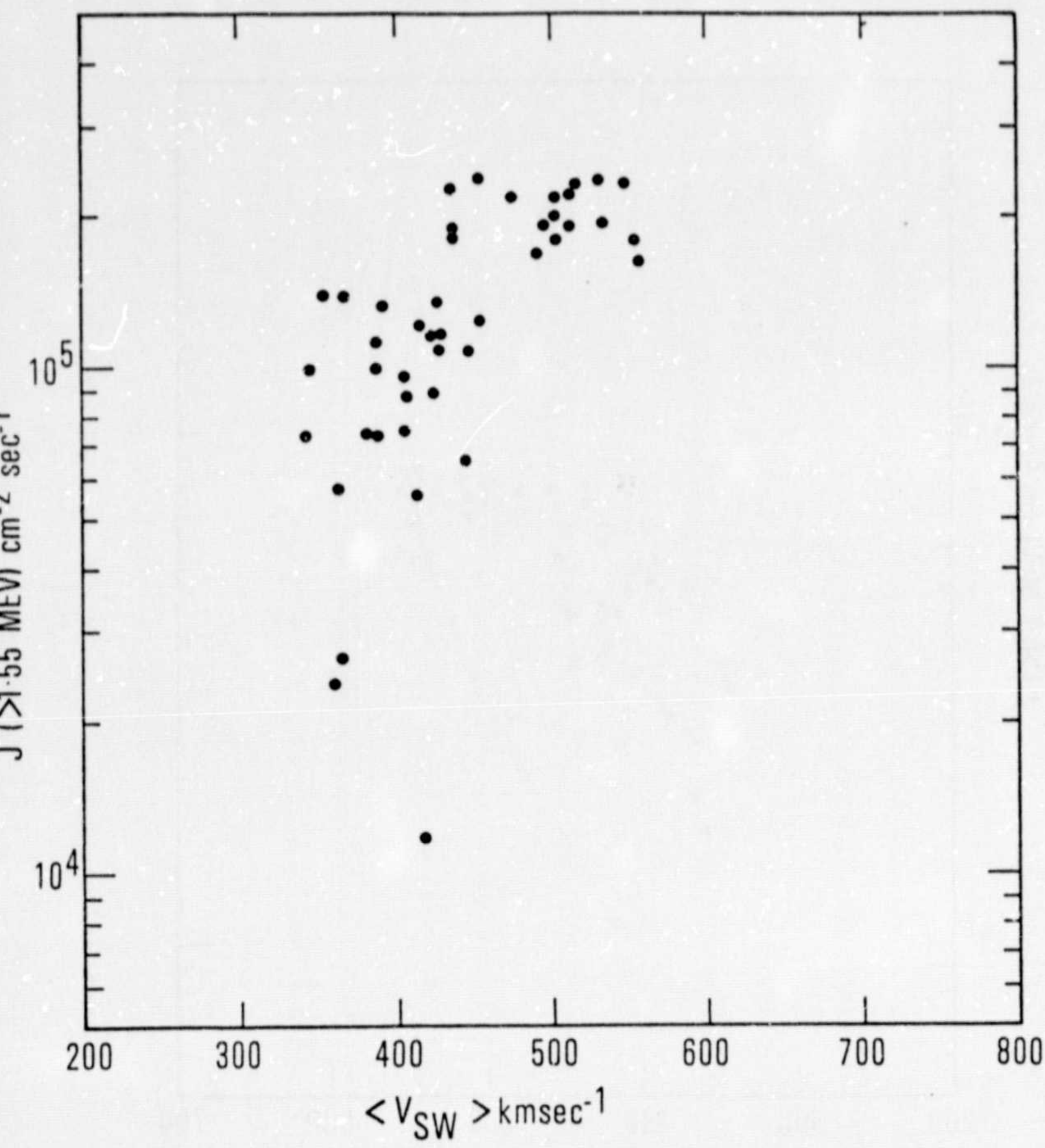

Figure 17. 27-day averages of energetic electrons (E > 1.55 MeV) as a function of corresponding averages of the solar wind velocity. All ATS-6 data for solar rotations 1927-1969 (June 1974 - August 1977) are included in this figure.

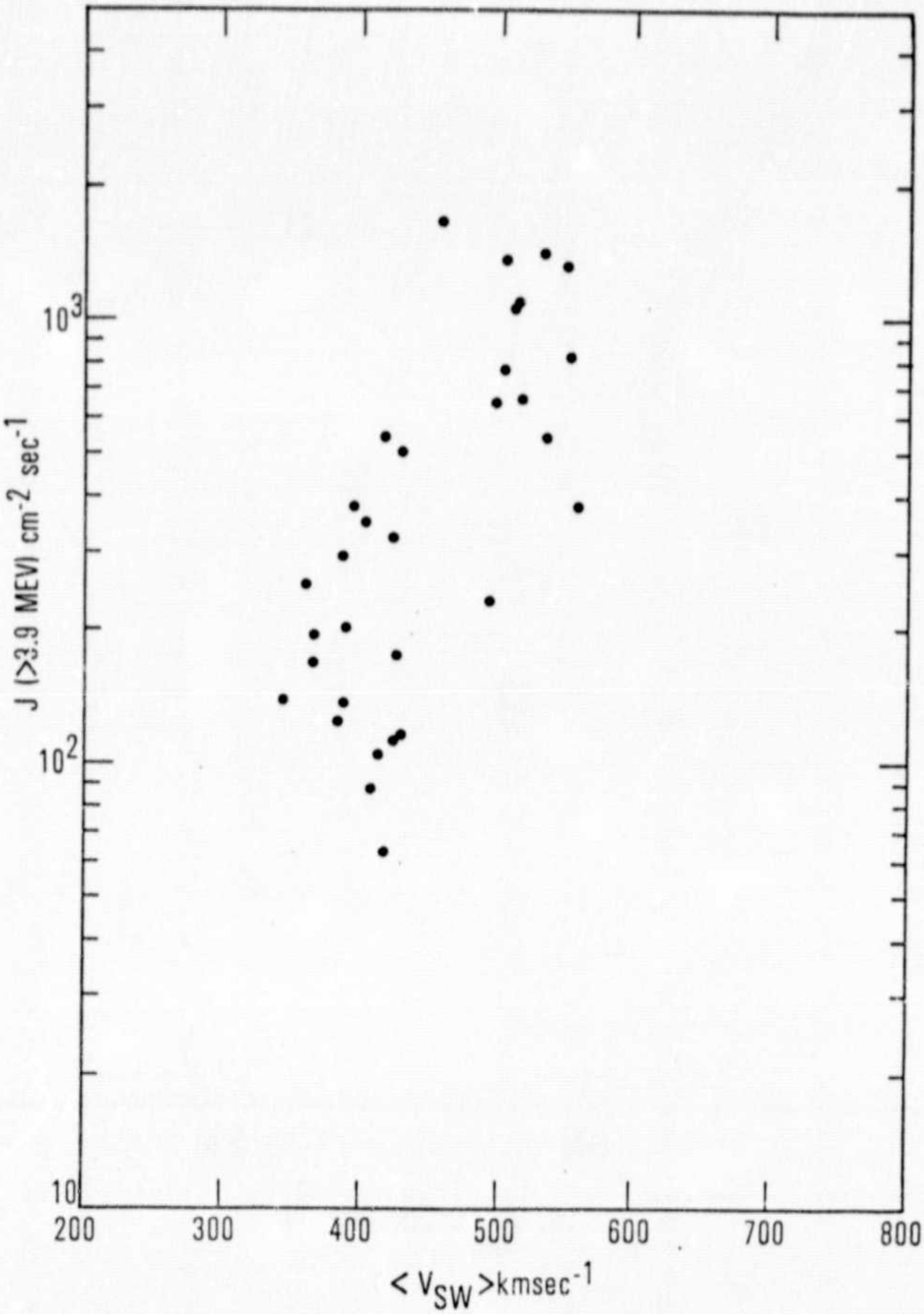

Figure 18. 27-day averages of energetic electrons (E > 3.9 MeV) as a function of corresponding averages of the solar wind velocity. All ATS-6 data from June 1974 through August 1977 are included in this figure, except for a period from mid 1975 through early 1976.

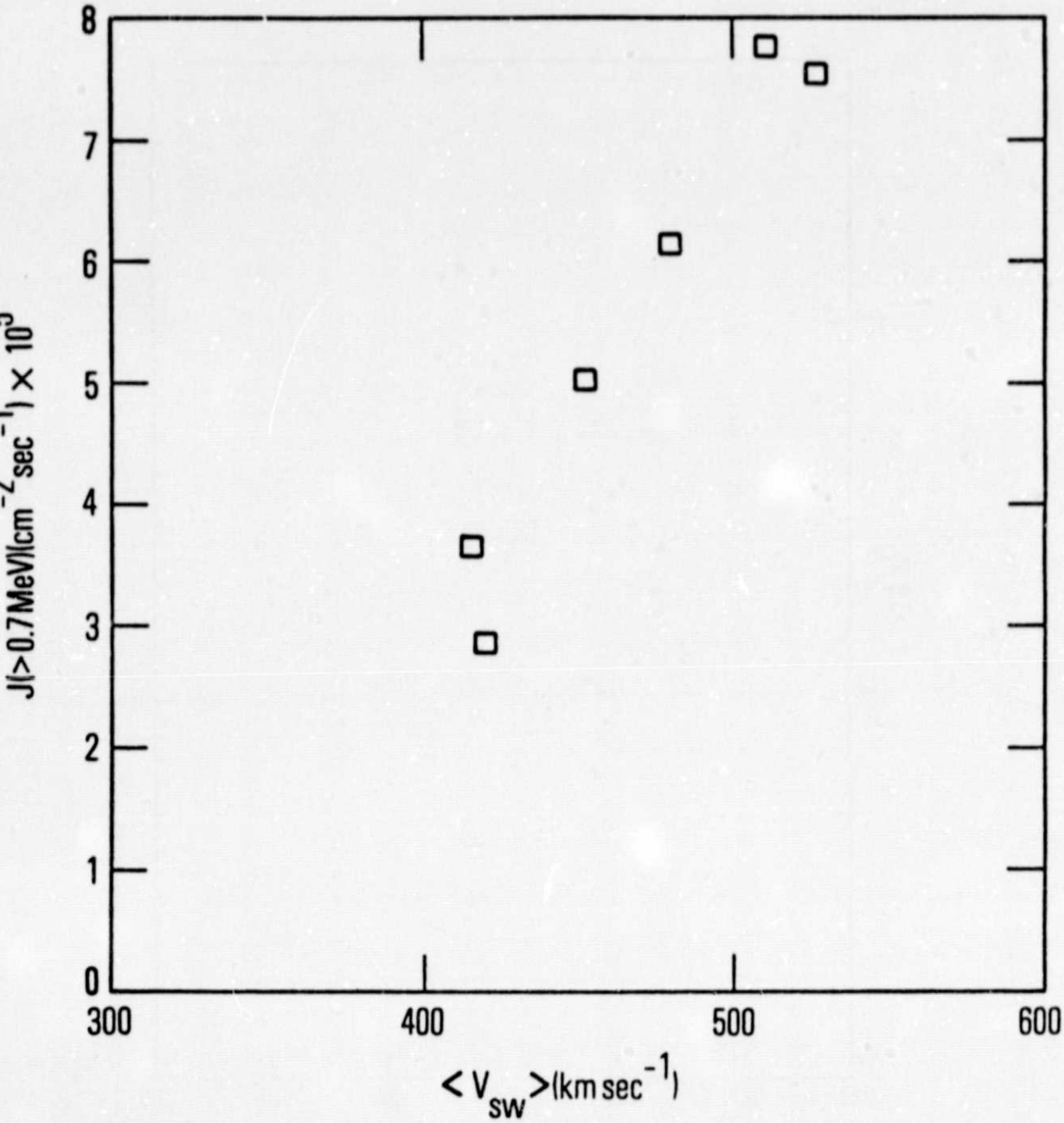

Figure 19. Plot of the semi-annual average of the E > 0.7 MeV electron flux as a function of the semi-annual average of the solar wind velocity. ATS-6 data from mid 1974 through 1977 are included in this plot.

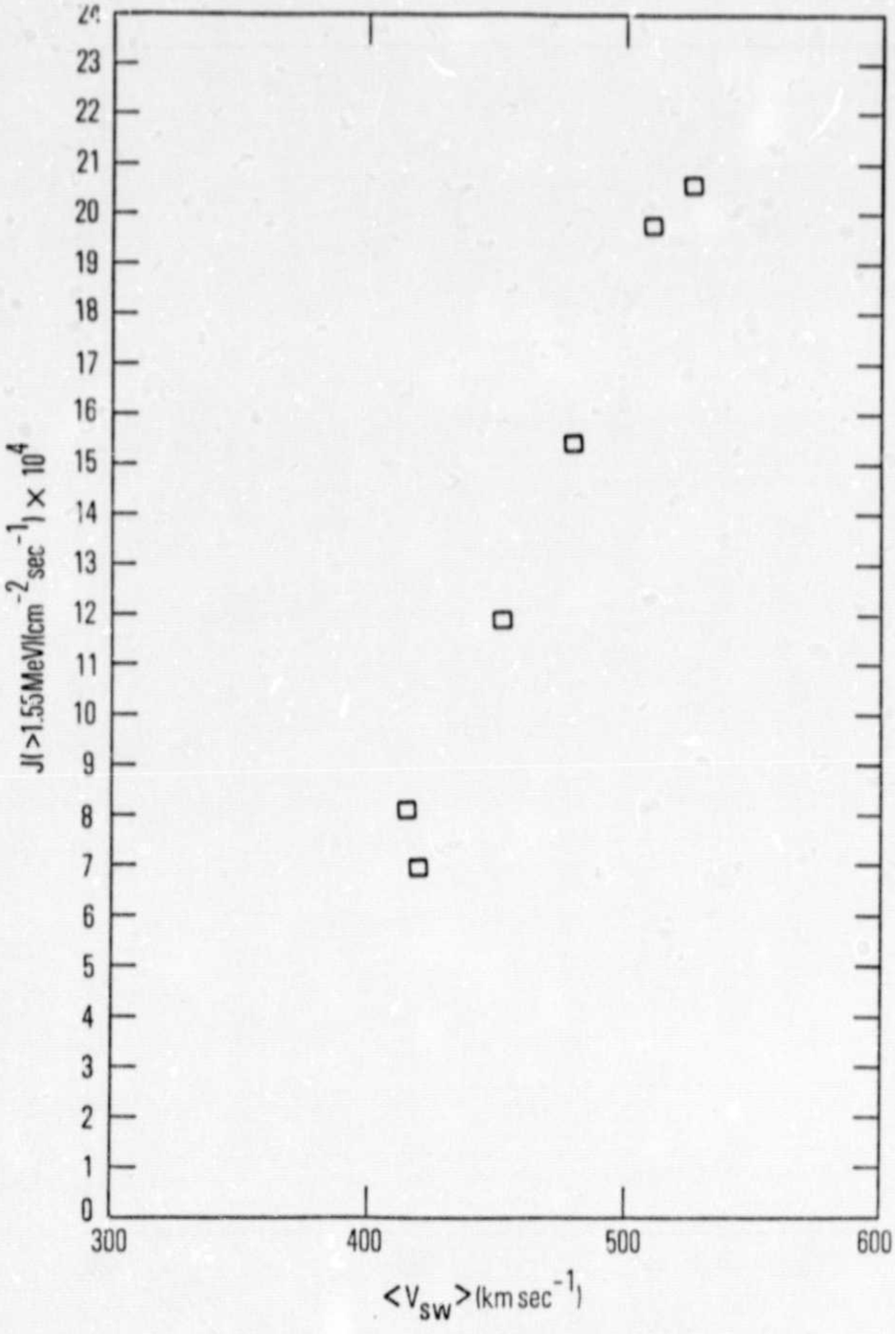

Figure 20. Plot of the semi-annual average of the E > 1.55 MeV electron flux as a function of the semi-annual average of the solar wind velocity. ATS-6 data from mid 1974 through 1977 are included in this plot.

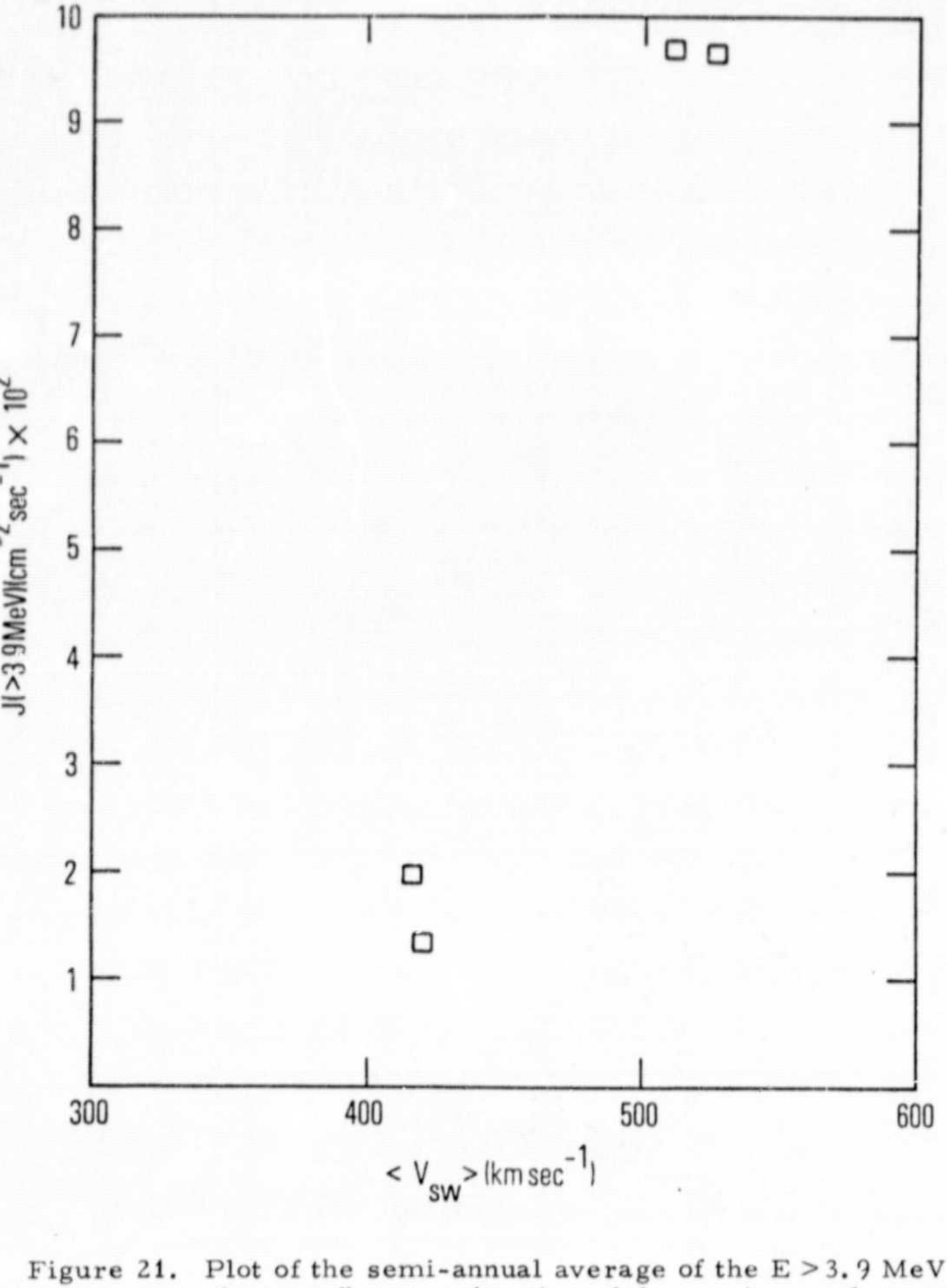

Figure 21. Plot of the semi-annual average of the E > 3.9 MeV electron flux as a function of the semi-annual average of the solar wind velocity. ATS-6 data from mid 1974 through 1977 are included in this plot, excepting the semi-annual average for the last half of 1975 and the first half of 1976.

The data and results presented in this paper may still be modified by elimination of adiabatic effects from our data base and by a detailed analysis of the generation and transport process which affect energetic electrons. We have not explored the dependence of electric and magnetic fluctuations in the magnetosphere on solar wind parameters and how such fluctuations would affect the generation and transport of energetic electrons, although it is already known that some magnetic indices of interest scale as $B_z V^2$ (Svalgaard, 1977). Extension of our correlation to shorter timescales (< 1 hour) needs to be carried out, although we may be hampered in this respect by the very disparate timescales between the causes (substorms) of magnetospheric particle enhancements which occur in minutes or hours and the ultimate appearance of energetic electrons which occurs in days. However, it seems clear the the present results already offer some hope of both short-term and long-term prediction of the energetic electron radiation in the outer magnetosphere if a sufficiently accurate prediction of the parameters of the solar wind are available. We thus must look at one output of the variable sun - the solar wind - to understand the <u>very</u> variable magnetosphere.

References

Akasofu, S. -I., The roles of the north-south component of the interplanetary magnetic field on large-scale auroral dynamics observed by the DMSP satellite, Planet. Space Sci., 23, 1349, 1975.

Arnoldy, R. L., Signatures in the interplanetary medium for substorms, J. Geophys. Res., 26, 5189, 1971.

Baker, D. N., R. D. Belian, P. R. Higbie and E. W. Hones, Jr., High energy magnetospheric protons and their dependence on geomagnetic and interplanetary conditions, J. Geophys. Res., (to be published), 1978.

Bame, S. J., J. R. Asbridge, W. C. Feldman, and J. T. Gosling, Solar cycle evolution of high-speed solar wind streams, Astrophys. J., 207, 977, 1976.

Burch, J. L., Effects of interplanetary magnetic sector structure on auroral zone and polar cap magnetic activity, J. Geophys. Res., 78, 1047, 1973.

Burton, R. K., R. L. McPherron, and C. T. Russell, The terrestrial magnetosphere: A half-wave rectifier of the interplanetary electric field, Science, 189, 717, 1975.

Caan, M. N., R. L. McPherron, and C. T. Russell, Characteristics of the association between the interplanetary magnetic field and substorms, J. Geophys. Res., 82, 4837, 1977.

Crooker, N. U., J. Feynman, and J. T. Gosling, On the high correlation between long-term averages of solar wind speed and geomagnetic activity, J. Geophys. Res., 82, 1933, 1977.

Dessler, A. J., and T. W. Hill, Comment on "On the high correlation between long-term averages of solar wind speed and geomagnetic activity," by N. U. Crooker, J. Feynman and J. T. Gosling, J. Geophys. Res., 82, 5644, 1977.

Feldman, W. C., J. R. Asbridge, S. J. Bame, and J. T. Gosling, Long term variations of selected solar wind properties: IMP 6, 7 and 8 results, J. Geophys. Res., (to be published), 1978.

Fritz, T. A., J. P. Corrigan, and the ATS-6 Experimenters, Significant initial results from the environmental measurements experiment on ATS-6, NASA Technical Paper 1101, December 1977.

Garrett, H. B., A. J. Dessler and T. W. Hill, Influence of solar wind variability on geomagnetic activity, J. Geophys. Res., 79, 4603, 1974.

Gosling, J. T., J. R. Asbridge, and S. J. Bame, An unusual aspect of solar wind speed variations during solar cycle 20, J. Geophys. Res., 82, 3311, 1977.

Gosling, J. T., J. R. Asbridge, S. J. Bame, and W. C. Feldman, Solar wind speed variations: 1962-1974, J. Geophys. Res., 81 (28), 5061, 1976.

Kivelson, M. G. and C. T. Russell, Dependence of the polar cusp on the North-South component of the interplanetary magnetic field, J. Geophys. Res., 78, 3761, 1973.

Paulikas, G. A., and J. B. Blake, Modulation of trapped energetic electrons at 6.6 R_e by the direction of the interplanetary magnetic field, Geophys. Res. Lett., 3, 227, 1976.

Paulikas, G. A., J. B. Blake and S. S. Imamoto, ATS-6 energetic particle radiation measurements at synchronous altitude, IEEE Trans. Aerospace and Electronic Systems, AES-11, 1138, 1975.

Paulikas, G. A., J. B. Blake, S. C. Freden and S. S. Imamoto, Observations of energetic electrons at synchronous altitude, 1. General features and diurnal variations, J. Geophys. Res., 73, 4915, 1968.

Russell, C. T., The solar wind and magnetospheric dynamics, in Correlated Interplanetary and Magnetospheric Observations, edited by D. E. Page, p. 3, D. Reidel Publishing Company, Dordrecht-Holland, 1974.

Russell, C. T. and R. L. McPherron, Semiannual variation of geomagnetic acitivity, J. Geophys. Res., 78, 92, 1973.

Russell, C. T., R. L. McPherron, and R. K. Burton, On the cause of geomagnetic storms, J. Geophys. Res., 79, 1105, 1974.

Singley, G. W. and J. I. Vette, A model environment for outer zone electrons, NASA Report NSSDC-72-13, December, 1972.

Svalgaard, L., An atlas of interplanetary sector structures 1947-1975, Stanford University Institute for Plasma Research, Report 648, February 1976, also subsequent private communications.

Svalgaard, L., Geomagnetic activity: Dependence on solar wind parameters, Coronal Holes and High Speed Wind Streams, ed. by J. B. Zirker, Colo. Asso. Univ. Press, Boulder, 1977.